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METHODS FOR TEMPERATURE MEASUREMENT OF PETROLEUM AND ITS PRODUCTS

PART 1 AT ATMOSPHERIC PRESSURE

(*First Revision*)

UDC 665·6 : 536·5

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NEW DELHI 110002

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March 1984

Indian Standard

METHODS FOR TEMPERATURE MEASUREMENT OF PETROLEUM AND ITS PRODUCTS

PART 1 AT ATMOSPHERIC PRESSURE

(*First Revision*)

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Indian Standard

METHODS FOR TEMPERATURE MEASUREMENT OF PETROLEUM AND ITS PRODUCTS

PART 1 AT ATMOSPHERIC PRESSURE

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part 1) (First Revision) was adopted by the Indian Standards Institution on 14 November 1983, after the draft finalized by the Petroleum Measurements Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

0.2 This standard was first published in 1961. In the present revision, the standard has been reviewed and revised in light of recent advances in the field of petroleum measurements. In this revision, the deep-cup case apparatus for the determination of temperature has been deleted. Although this form of sampling device for temperature determination is in common use, but it has been found to be unsatisfactory in practice providing unreliable results due to heat loss and due to difficulties in obtaining true samples from desired levels. Also, the immersion timings vary between 5 and 30 minutes which are inconveniently long periods. Modified cup-case instruments provided with a variety of valving arrangements have not been found to give more reliable results. Further, in this revision, a few more ranges of thermometers have been included and the sampling procedure improved suitably.

0.3 The correct determination of temperature is essential in all measurements of oil in bulk storage since errors may seriously affect the accuracy of calculated quantities. The need for care in all measurements cannot, therefore, be over-emphasized. In all calculations concerning the measurement of oil in bulk, the mean temperature of the oil in each container is required; and the object of this standard is to lay down methods which will enable accurate determination of this temperature.

0.4 This standard (Part 1) covers methods for temperature measurement of petroleum and its products at atmospheric pressure (*see* **1.1**). The Part 2 of the standard covers methods for measurement of temperature of petroleum and its products, in liquid state and in bulk, at above the atmospheric pressure.

0.5 Taking into consideration the views of producers, distributors and the consumers, the Sectional Committee responsible for preparation of this standard felt that it should be related to the trade practices followed in the country in this field. Furthermore, due weightage had to be given to the need for international co-ordination among standards prevailing in different countries of the world in this field. These considerations led the Sectional Committee to base this standard on the standards and other publications issued by the Institute of Petroleum (IP), London, and American Society for Testing Materials (ASTM), Philadelphia and International Organization for Standardization (ISO).

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 1) prescribes the methods for determining temperatures of petroleum and its products when in a liquid state and in bulk, at atmospheric pressure.

2. GENERAL PRECAUTIONS

2.0 The precautions outlined below are applicable whenever the temperature of a bulk quantity of oil is required to be determined. Certain special precautions which are necessary in applying some of the equipment specified are described at appropriate places.

2.1 Frequently the contents of a storage vessel are not uniform in temperature. Temperature shall, therefore, be obtained from a sufficient number of points within the bulk to enable the most reliable estimate of the mean temperature of the stock to be made. The number of these temperature readings, depends on the physical properties of the oil and on operating conditions, and the appropriate clauses should be referred to for guidance in any particular case.

2.2 Whatever apparatus is used for taking samples for temperature measurement, the general precautions given in IS : 1447-1966† and the

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*Rules for rounding off numerical values (*revised*).

†Methods of sampling of petroleum and its products.

following general precautions shall always be observed whenever applicable :

a) The temperature of each sample drawn shall be recorded immediately after the readings is taken. The number of the tank or the container, the position of the dip-hatch, and the level from which each sample is drawn shall be clearly indicated in the gauger's notes.

b) Temperature determinations for reference purposes shall be made in duplicate under the immediate supervision of a person of skill having previous experience in oil measurement. Readings shall be recorded immediately and agreed by interested parties before they leave the tank or container.

c) Whenever determinations on the contents of a container are made before and after a movement of a bulk quantity of oil, the same general procedure shall be followed in each case.

d) Samples for temperature determination shall be taken through openings giving direct access to the bulk of oil in container. In the case of floating roof tanks, the samples for temperature determination may be taken through the dip-pipe as mentioned in **12** of IS : 1518-1980*.

e) Temperatures shall not be taken within 450 mm of the walls of a container in order to avoid extraneous thermal effects. In older tanks, gauge hatches and roof manholes may be situated nearer the tank shell. In such cases it is recommended that the opening through which temperatures are taken shall be chosen preferably on the side of the tank most sheltered from the prevailing wind and the sun and at a position which will enable the measurements to be taken as far from the shell as possible. Consideration shall also be given to the provision of a new gauge hatch opening in the preferred position.

   In new tankages, it is recommended that gauge hatches should be positioned with their centres not less than 450 mm from the tank shell and oriented clear of bottom fittings. The accuracy of a mean temperature is improved by taking readings at more than one dip-hatch. Where temperature gradients are likely to warrant consideration of additional sampling points, as in artificially heated product tankage, the following table may be taken as a guide. Safety or other local regulation may, however, preclude the use of more than one dip-hatch in volatile product tankage, unless vapour-tight gauging devices are used.

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*Method for gauging of petroleum and liquid petroleum products (*first revision*).

Tank Diameter metre	*No. of Hatches*
Below 20	1
20-30	2
Above 30	3

When two hatches are fitted these shall be situated approximately on the same diameter and when three hatches are fitted, they shall be spaced on radii at approximately 120°. As far as is practicable, the hatch or hatches shall also be oriented in such positions that the maximum protection is afforded against, the effects of the sun and prevailing wind on the sides of the tank.

f) Temperature measurements shall be made immediately after the storage vessel is gauged.

g) When more than one sampling level is involved, samples shall be drawn in the order upper, middle, and lower so that layers which have not yet been sampled are not unnecssarily disturbed.

h) The depth of free water in the storage vessel shall be ascertained before temperature determinations are made so that the correct level for the latter may be properly determined.

j) When protective metal cases (*see* **3.3.2** and Fig 4A and 4B) for thermometers are used they shall permit free access of the oil to the thermometer bulb, and ample provision shall be made for viewing the scale. Sufficient time must always be allowed for the case to take up the temperature of the oil before the determination is made.

k) It is strongly recommended that storage vessels containing volatile products should not be opened during electrical storms.

2.3 Safety Precautions — The safety precautions as mentioned under **19** of IS : 1518-1980* shall also be followed.

3. APPARATUS

3.1 Sampling Apparatus — The ‘ weighted sampling cans ’ of the type described in **3.1.1** and **3.1.2** and sampling cage as described in **3.1.3** shall be used.

3.1.1 *Normal Type Weighted Sampling Can* — This can (Fig. 1) may be made of tinplate, copper, or brass. It shall be deep enough to accommodate the whole length of the indicating column of the thermometer over the

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*Method for gauging of petroleum and liquid petroleum products (*first revision*).

range of normal reading, and shall be of sufficient capacity to obviate rapid cooling of its contents. This is particularly important for volatile products and whenever there is substantial difference between ambient and oil temperatures. As a sample for qualitative or other purposes is frequently required when bulk measurements are made, a sampling can of 800 to 1 000 ml capacity will be found convenient. The dimensions shown in Fig. 1 give a capacity of approximately 800 ml. Increased capacity may be obtained by increasing the overall length while adhering to the maximum outside diameter. It shall be of such a weight as to sink rapidly in the material to be sampled. The metal used to weigh the apparatus shall either be fitted externally or be contained in a liquid-tight space provided by fitting the can with a false bottom. The apparatus shall be provided with means to permit filling at any desired level; and the can shall have a suitable long chain or cord of non-sparking material attached to it.

3.1.2 *Double-Walled Weighted Sampling Can* — This can (Fig. 2) may be made of copper or brass, and consists of a thin walled inner container having tapered neck and a rounded bottom, held centrally by three spacing lugs inside a flat-bottomed outer jacket made of thicker sheet of metal and extending to the upper edge of its neck. The apparatus shall have an outside diameter such that it will freely pass through a tank dip-hatch. The inner container shall have a capacity of 800 to 1 000 ml and shall have an outside diameter such that the distance between the inner container and outer jacket shall be about 11 mm. The outer jacket shall be pierced with six equally spaced holes, 13 mm in diameter close to the neck of the inner container and one 32 mm diameter hole drilled centrally in the base. In the annular space between the inner container and the outer jacket a well shall be provided to fit a thermometer (*see* **A-1**). This well shall be so constructed that when the annular space is filled with oil, the oil shall flow freely round the bulb and stem of the thermometer. The lower end of the well shall be fitted with a spring-loaded cup to prevent breakage of the thermometer bulb, and the upper end shall be provided with a cap closed with a bayonet fastening. The well shall be of such a length that when the cap is removed, about 25 mm of the stem of the thermometer is left exposed. The apparatus shall be fitted with a strong handle made of brass wire and the inner container shall be closed with a well-fitting cork. The cork and the can shall have a suitable cord or chain of sufficient length attached to permit the can to be filled at any desired level. The apparatus shall be of sufficient weight to sink rapidly in the material to be sampled and, if necessary, additional weight may be provided by fitting a piece of lead to the inside of the base of the outer jacket.

3.1.3 *Sampling Cage with Glass Bottle* — It consists of a metal holder or cage of suitable dimensions to take bottles or cans of both half litre and one litre capacity as shown in Fig. 3. The apparatus, including the can

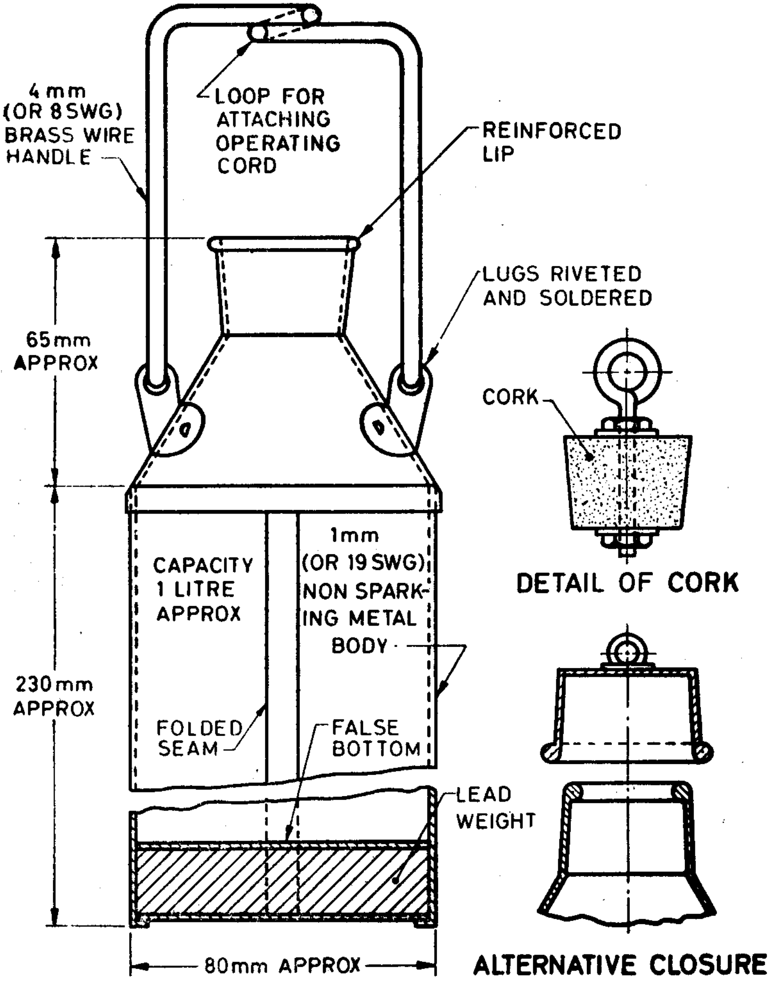
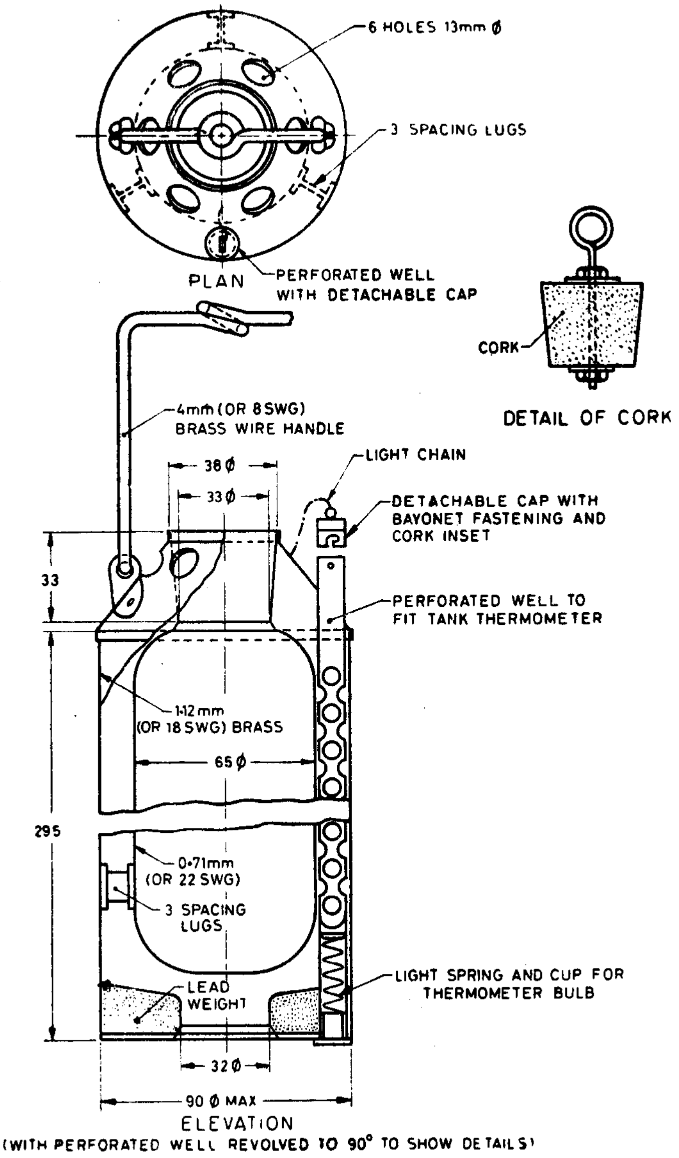


FIG. 1 WEIGHTED SAMPLING CAN — NORMAL TYPE


6 HOLES 13mm ⌀
3 SPACING LUGS
PLAN
PERFORATED WELL WITH DETACHABLE CAP
CORK
DETAIL OF CORK
4mm (OR 8 SWG) BRASS WIRE HANDLE
LIGHT CHAIN
38 ⌀
33 ⌀
DETACHABLE CAP WITH BAYONET FASTENING AND CORK INSET
33
PERFORATED WELL TO FIT TANK THERMOMETER
1·12 mm (OR 18 SWG) BRASS
65 ⌀
295
0·71mm (OR 22 SWG)
3 SPACING LUGS
LEAD WEIGHT
LIGHT SPRING AND CUP FOR THERMOMETER BULB
32 ⌀
90 ⌀ MAX
ELEVATION
(WITH PERFORATED WELL REVOLVED TO 90° TO SHOW DETAILS)

All dimensions in millimetres.

FIG. 2 DOUBLE-WALLED WEIGHTED SAMPLING CAN

or bottle, shall be of such a weight as to sink readily in the material to be sampled, and provisions shall be made to permit filling the bottle or can at any desired level.

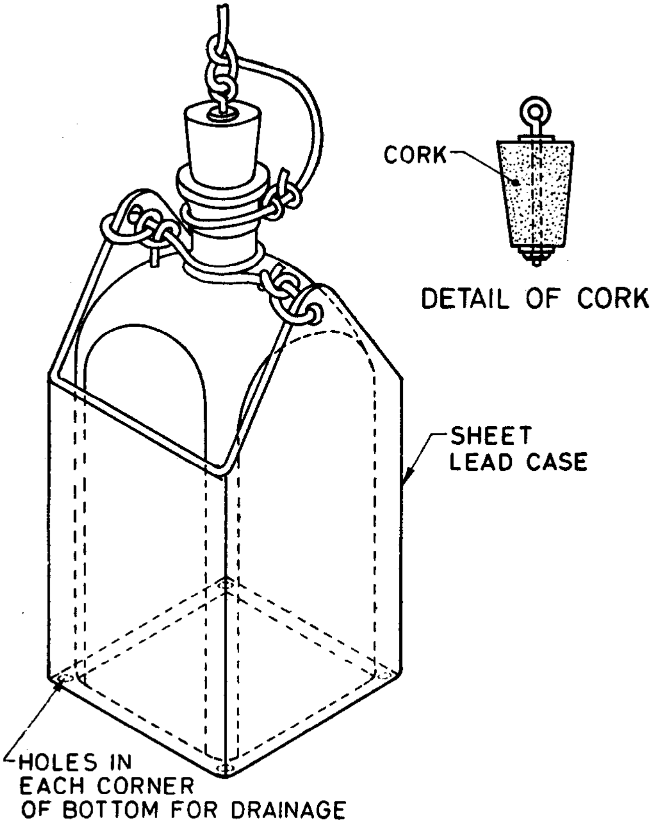


Fig. 3 Sampling Cage

3.2 Use of Sampling Apparatus

3.2.1 The double walled sampling can (*see* **3.1.2**) with provision for preheating the thermometer is recommended for use with both heated and unheated oils.

3.2.2 The normal type weighted sampling can (*see* **3.1.1**) may also be used for taking samples for temperature measurement. It has been found, however, that erroneous results are liable to be obtained with this type of sampling can. If this is used when oil and ambient temperature differ by more than 15°C, as for example, with artificially heated oils. Certain weather or climatic conditions may also affect results, for example, high winds or tropical sunshine. In these circumstances, unheated products may show lower or higher temperatures than actual. Similarly products which are substantially above ambient temperatures may cool appreciably before the temperature can be recorded. This apparatus shall not, therefore, be used under these conditions.

NOTE — It is common practice to employ armoured case thermometers for use with the sampling can method of tank temperature determination, however, because their use may involve appreciable errors due to the thermal capacity of the case and to the greatly increased thermal response time, their use is not recommended where accurate temperatures are required.

3.2.3 The choice of sampling apparatus will, therefore, depend upon circumstances, but, whichever apparatus is used, it shall conform to the requirements of **3.1.1** to **3.1.3** and the following directions shall be observed :

a) The sampling can, with the cork inserted, shall be lowered to the required level and kept there for a sufficient time so that it attains the temperature of the surrounding oil. The time required for the can to reach the equilibrium temperature will depend on the physical properties of the oil [*see also* **3.2.3** (g and h)]. The can shall be raised and lowered repeatedly over a distance of about 30 to 60 cm during this time, in order to accelerate heat transfer.

b) When the sampling can has remained in the oil for the required time, the cork shall be withdrawn and the can allowed to fill. When full, the can shall be hauled as rapidly as possible to the tank top. The thermometer shall then be inserted immediately in the can and the contents gently stirred with it until a steady reading is obtained, care being taken to keep the thermometer bulb immersed during reading so that only the shortest possible length of the thread emerges out of the oil.

c) With the double walled can, the thermometer shall be placed in the well provided for the purpose, and lowered with the can into the tank. On withdrawal of the can the thermometer shall be quickly removed from the well and inserted in the can as prescribed in **3.2.3**(b).

d) When the reading has become steady the thermometer shall be read to the nearest 0·25°C and the reading recorded immediately against the level at which the sample has been taken. The average of all temperatures obtained rounded off to the nearest 0·5°C shall be taken as the mean temperature of the tank contents.

e) The temperature reading shall be taken with the minimum of delay as external influences act very quickly on the sampling device and its contents, particularly when the normal type of can is used. Care shall be taken to shield it from adverse effects of the weather both before and during the reading of the thermometer. This may be done by keeping it inside the hatch opening.

f) In order to prevent the formation of an insulation film of heavy oil in the sampling device after it has been used with bitumen, fuel oil or heavy lubricating oil, it shall be thoroughly rinsed out with kerosene or gas oil and drained, and the thermometer shall be cleaned and wiped dry with a cloth.

g) In case where oil and ambient temperatures differ by more than 15°C, the principles laid downi n **3.2.3** (a) to **3.2.3** (f) shall be followed when using the double-walled sampling can, but the immersion time before the cork is removed shall be increased to 3 minutes, the agitation of the can being maintained during the period.

h) When using normal type sampling can or sampling cage, they shall be kept immersed in oil at the required level, for the following minimum period to reach temperature of the surrounding product :

Product in Which Can is Immersed	*Time* minutes
Oils of kinematic viscosity less than 10 centistokes at 50°C (or of less than 90 seconds* Redwood No. 1 at 38°C). *Examples* : Motor and aviation gasoline, kerosene, gasoil and light spindle oil	1
Crude oils and all other products of higher viscosity	2

The can shall be raised and lowered repeatedly a distance of about 0·5 m, during this time, in order to accelerate heat transfer.

3.3 Thermometers

3.3.1 *Liquid-in-Glass Type Thermometers*

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*This is approximate equivalent and not exact conversion.

3.3.1.1 Thermometers recommended in Appendix A shall be used. The following precautions shall be taken when selecting and using liquid-in-glass thermometer :

a) Only thermometers conforming to the specifications given in **A-1.1** and **A-1.2** shall be used.

b) The range of the thermometer used shall be selected so that preferably the expected temperature reading will not be within 5°C of the terminal scale marks.

c) Errors due to parallax should be avoided. The thermometer shall be held at the eye level so that the line of vision is perpendicular to the stem when the reading is taken.

d) When a thermometer is not used under required immersion conditions, it may be necessary to apply an emergent-stem correction (*see* **A-3**) in order to obtain the correct reading.

e) When a thermometer filled with toluene, alcohol or similar liquid is used for measuring extremely low temperatures, reading shall be taken with the thermometer in a vertical position to allow drainage of the thermometric liquid down the bore of the thermometer.

f) When a thermometer has lost a substantial amount of pigment from its engraving, reading becomes difficult and errors may easily arise. The thermometer should then be discarded or have its engraving refilled with a suitable black pigment. The pigment shall be inert and resistant to oil and under no circumstances shall a pigment requiring any form of heat-treatment be used.

3.3.1.2 For detection and prevention of errors in liquid-in-glass thermometers, the following general directions shall be observed :

a) Thermometer shall be compared with a standard thermometer before they are issued.

b) Sudden heating or cooling of liquid-in-glass thermometers may affect their accuracy and when instruments are used at high temperatures they may develop permanent errors owing to slight softening and distortion of the glass of the bulb. It is important, therefore, that thermometers shall also be compared periodically with the standard thermometer. The frequency of comparisons will depend upon the use to which the thermometers have been put, but it is recommended that yearly intervals should not be exceeded. Thermometers which are in constant use shall, however, be checked at approximately half-yearly intervals by the method recommended in **A-2.**

c) Defects which are commonly encountered in mercury-in-glass thermometers are :

  i) Broken threads.

  ii) The separation of globules of mercury which then collect in the expansion chamber at the top of the thermometer.

  iii) Gas bubbles which get trapped in the bulb due to shaking up in transport.

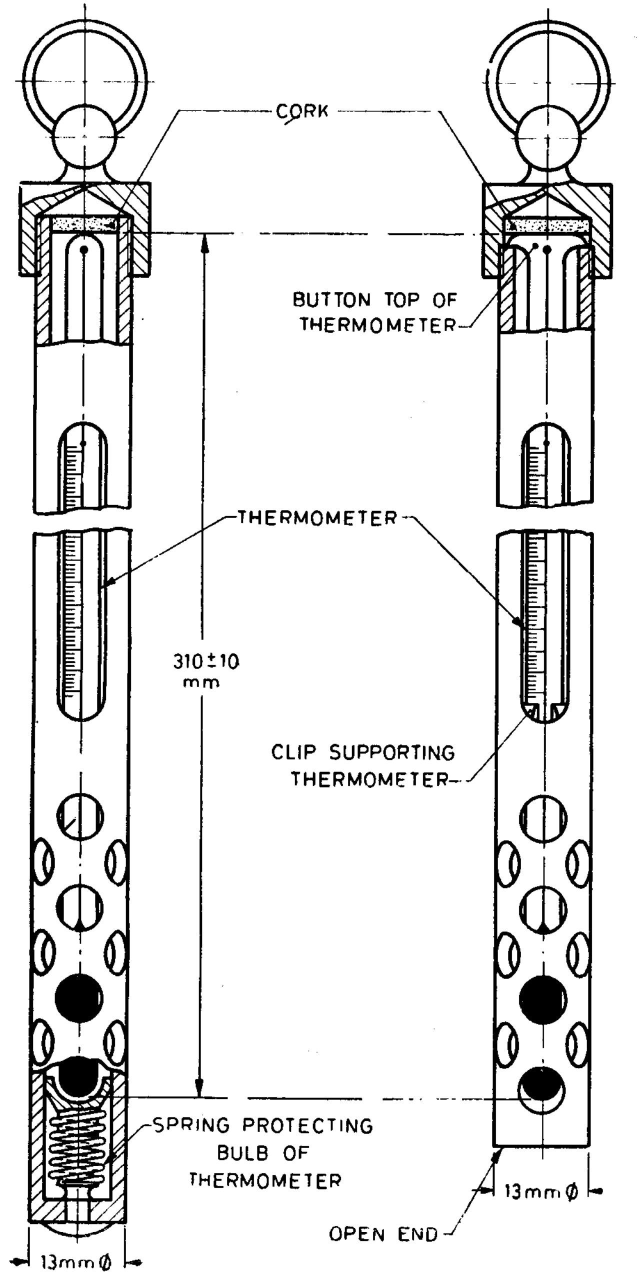
Thermometers shall be therefore, carefully examined on each occasion before use, and if any thermometer is found to be defective it shall be withdrawn from use and another one employed.

NOTE — A thermometer with fault (i) can often be returned to normal by shaking the instrument carefully while it is in a vertical position. Faults (i) and (iii) can usually be rectified by cooling the bulb of the thermometer with solid CO_2, while fault (ii) can be corrected by cautiously heating the thermometer to drive the thread into the expansion chamber when a gentle shake will often reunite the globules of mercury with the thread. Before being taken into use again, an instrument which has been so repaired shall be checked against a standard thermometer.

3.3.2 *Armoured Case for Thermometers*

3.3.2.1 *Normal type* — The normal type armoured case shall be made of non-sparking metal not greater than 13 mm outside diameter. It shall be constructed as shown in Fig. 4A. The cut-away portion shall be of such dimensions as will permit the whole of the scale of the thermometer to be clearly visible. The portion of the cage enclosing the bulb of the thermometer shall be pierced with a sufficient number of holes of such dimensions (approximately 6 mm diameter) as will permit an easy access of oil to the thermometer bulb without reducing the effective strength of the case. A clearance of at least 2 mm between thermometer bulb and inside of the armoured case should be maintained.

3.3.2.2 *Top suspension type* — An alternative type of armoured case is illustrated in Fig. 4B. The main drawback of this type of case is that special thermometers are required which are finished with a flattened button top. They are, however, preferable to the normal type of armoured case in that the flow of oil round the thermometer bulb is less impeded, owing to the open end. The case shall be made of non-sparking metal not greater than 13 mm outside diameter. The cut-away portion shall be of such dimensions as will permit the whole of the scale of the thermometer to be clearly visible. The portion of the case enclosing the bulb shall be pierced with a sufficient number of holes of such dimensions (approximately 6 mm diameter) as will permit easy access of the oil to the thermometer bulb.


CORK
BUTTON TOP OF THERMOMETER
THERMOMETER
310 ± 10 mm
CLIP SUPPORTING THERMOMETER
SPRING PROTECTING BULB OF THERMOMETER
13 mm ∅
OPEN END
13 mm ∅

4A Normal Type   4B Top Suspension Type

FIG. 4 ARMOURED THERMOMETER CASE

4. PROCEDURE

4.0 General Method

4.0.1 It is often a matter of some difficulty to obtain a truly representative temperature at any one level within a liquid when its temperature differs considerably from the ambient temperature, as for example, in the case of heated oil. Individual cases shall be treated on their merits and it may be necessary to take temperatures at more than one sampling point if unequal temperatures at any one level are suspected. The advisability of circulating the contents of the tank should also be considered.

4.0.2 Considerable care shall be exercised in sampling heated tanks for temperature measurement. When heating coils have been on for a sufficient time for the tank contents to attain a steady temperature, little difficulty in obtaining accurate temperatures will usually be experienced, but samples shall not be drawn from within 30 cm of the steam coils. If the steam coils have been turned off for any appreciable time, uneven temperatures will often be encountered and accurate mean temperature will be difficult to obtain. Circulation of the tank contents or fresh application of steam to the coils will help to overcome the difficulty, but in the latter case it is, of course, most important to allow sufficient time for the tank contents to reach a new steady temperature before attempting to take samples. It is impossible to lay down hard and fast rules for permissible time intervals as heating and cooling rates of tanks will depend on the size and shape of the tank, design of steam coils, atmospheric conditions, etc.

4.1 Liquids in Non-Pressure Tanks (at or Near Ambient Temperature) — The following procedures are applicable to the measurement of the temperature of all liquid petroleum products contained in non-pressure storages, only when the difference between the oil and ambient temperature does not exceed 15°C.

4.1.1 *Vertical, Fixed and Floating-Roof Tanks*

4.1.1.1 Samples for temperature determination shall normally be drawn from one dip-hatch or in the case of floating roof from dip-pipe. The average temperature at the hatch shall be taken as the temperature of the whole tank contents.

4.1.1.2 In vertical tanks when the oil depth is greater than 4 metres, the upper, middle and lower samples shall normally be drawn at levels equivalent to one-sixth, one-half and five-sixths of the total oil depth. If the temperature of the middle sample does not differ from the average temperature of the three samples by more than 0·5°C, this average temperature shall be taken as the mean temperature of the tank contents. If this is not so, additional samples shall be drawn at nine-tenths, seven-tenths, and one-tenths of the oil depth. If the average temperature of these four samples and the middle sample does not differ from the average temperature of the previous upper, middle and lower samples by more than 0·5°C, then the average of all temperatures shall be taken as the mean temperature of the tank contents. If the difference is still greater than 0·5°C the process of taking additional samples and determining new average temperatures shall be repeated, although such a procedure will very seldom be required. Samples shall not, however, be drawn from levels less than 15 cm below the oil surface or less than 15 cm above the bottom of the oil layer.

4.1.1.3 When the oil depth is less than 4 metres and greater than 2 metres, two samples shall be drawn at levels equivalent to one-quarter and three-quarters of the oil depth. The average temperature of these two samples shall be taken as the mean temperature of the tank contents when this average temperature does not differ from the temperature of either sample by more than 0·5°C. When a difference greater than 0·5°C is found a middle sample shall also be drawn, and the average temperature of the three samples shall be taken as the mean temperature of the tank contents.

4.1.1.4 When the oil depth is less than 2 metres, one sample only need be taken. This sample shall be drawn from the level corresponding to one-half of the oil depth. The temperature of this sample shall be regarded as the mean temperature of the tank contents.

4.1.2 *Horizontal Cylindrical Tanks*

4.1.2.1 In horizontal cylindrical tanks which are full or nearly full, upper, middle and lower samples shall be drawn at levels equivalent to one-sixth, one-half and five-sixths of the oil depth. The temperature of these samples shall be read and recorded to nearest 0·25°C. The mean temperature shall then be taken as one-tenth of the sum of three times the temperature of the upper sample, four times the temperature of the middle sample, and three times the temperature of the lower sample, rounded off to the nearest 0·5°C.

4.1.2.2 The case of a partially filled horizontal cylindrical tank is one requiring the attention of an experienced operator. In general the levels chosen for sampling will be those corresponding to one-sixth, one-half and five-sixths of total volume of oil contained in the tank at the time temperatures are taken. These levels can, of course, be found only by reference to the tank capacity table. The arithmetic average of the temperatures recorded shall be taken as the temperature of the tank contents. When, however, the oil depth is less than 2 metres, one sample only need to be taken. The sample shall be drawn from the level corresponding to one-half of the oil depth. The temperature of this sample shall be regarded as the mean temperature of the tank contents.

4.1.2.3 When there is reason to suspect a variation of temperature between the ends of the tank, and when suitable hatches are fitted, upper, middle and lower temperatures shall be taken at each end of the tank. The arithmetic average of the temperatures at each end of the tank shall be calculated as in **4.1.1** and **4.1.2.2** and the mean temperature of the tank shall be taken as the arithmetic mean rounded off to the nearest 0·5°C of the two average temperatures so obtained.

4.1.3 *Tanks Mounted on Rail Cars and Road Vehicles*

4.1.3.1 In tanks having a single compartment, a middle sample only shall be taken. The temperature of this sample, read and recorded to the nearest 0·5°C, shall be regarded as the mean temperature of the tank contents.

4.1.3.2 If the tank is partitioned, a middle sample of each compartment shall be taken. The temperature of each sample shall be read and recorded to the nearest 0·25°C and the arithmetic average of these temperatures rounded off to the nearest 0·5°C shall be regarded as the mean temperature of the tank contents. When separate quantities are delivered from separate compartments of a partitioned tank, the middle temperature of each compartment shall be taken as the temperature of the oil delivered from it.

4.1.4 *Ship and Barge Cargoes*

4.1.4.1 Temperature determinations shall be done in each tank, at levels corresponding to one-sixth, one-half and five-sixths of the oil depth, that is, at levels from where samples are taken. The temperature of each sample shall be determined and recorded to the nearest 0·25°C. The mean temperature of each tank shall then be taken as the average temperature of the three samples without rounding off. The arithmetic average of these mean tank temperatures, rounded off to the nearest 0·5°C, shall then be taken as the mean temperature of the cargo. When the capacities of individual ship or barge tanks differ appreciably among themselves and wide variation in temperature has been found between individual tanks, a weighted average of the temperatures of tank contents shall be taken as the temperature of the cargo. The weighting shall be in proportion to the volume of product represented by each mean temperature.

4.1.4.2 In certain circumstances and provided all interested parties are in agreement, an abridged procedure may be followed. If a ship has just completed loading and the loading has not been unduly prolonged then it is probable that all the tanks of the ship will be at a similar temperature. This will be confirmed if the temperatures of upper, middle and lower samples from the first two tanks sampled show no appreciable difference. It will then be permissible to confine subsequent determinations of the samples to the middle temperature only. If agreement in temperature is still obtained on the next one or two tanks sampled, the number of tanks sampled may then be reduced to one tank in four, provided that the tanks so sampled are chosen in such a way that all sections of the ship are fairly represented. For large tankers not less than six tanks shall be sampled. For small vessels, such as lighters and barges, in which the total number of compartments does not exceed eight, temperatures need be determined on four compartments only; but where the total number of compartments is four or less, the temperature of each compartment shall be taken. The abbreviated procedure shall not be used when the cargo is made up of different products or grades, unless each grade occupies more than four tanks in which case each group of tanks may be tested by the abbreviated procedure. Otherwise, each tank shall be tested following the full procedure.

NOTE — Since there must be no undue delay in taking measurements in tankers, time can be saved by using more than one sampling device and keeping these immersed in the tanks while ullages are being taken.

4.2 Liquids in Non-Pressure Tanks (at Temperatures Differing by More Than 15°C from Ambient) — The following procedures are applicable to the measurement of the temperature of all liquid petroleum products in non-pressure storage when the oil and ambient temperature differ by more than 15°C.

4.2.1 *Vertical and Horizontal Tanks* — Procedure similar to those outlined in **4.1.1** and **4.1.2** shall be followed except that a tolerance of 1°C shall be permitted when deciding whether additional samples shall be taken at intermediate levels. When the contents of a tank are suspected to be stratified, the time may be saved by taking samples at regular intervals of oil depth. A distance of about 1·2 to 1·5 metres between adjacent samples will usually be found to be adequate. Temperature determinations shall not be done from levels less than 15 cm below the oil surface or less than 15 cm above the bottom of the oil layer. Each temperature shall be read and recorded to the nearest 0·5°C and the arithmetic average of the temperatures, so recorded, rounded off to the nearest 0·5°C, shall be regarded as the mean temperature of the tank contents.

4.2.2 *Tanks Mounted on Rail Cars and Road Vehicles* — The procedure as given in **4.1.3** shall be followed.

4.2.3 *Ship and Barge Cargoes* — The full procedure as laid down in **4.1.4** shall be followed. However, the abridged procedure shall not be used in view of the variations in temperature likely to be found in individual tanks due to the cooling effects of the sides of the ship.

4.3 The temperature measurement of crude oils, gasolines, and other volatile products when these are contained in vapour-tight tanks shall be carried out as described in **3.2.3**.

APPENDIX A

(*Clauses* 2.2 *and* 3.3.1)

LIQUID-IN-GLASS THERMOMETERS

A-1. SPECIFICATIONS

A-1.1 All thermometers shall conform to the general requirements given below, but any other suitable range thermometer could be used (except for bitumen tank) subject to the following conditions :

a) The temperature range between minimum and maximum should not exceed 85°C;

b) The thermometers shall meet all specifications given under col 2 of Table 1 except the temperature range;

c) The size of expansion chamber should allow for the heating up to 50°C higher than the maximum temperature of the thermometer.

NOTE — The thermometers with front lens tubing are also permissible.

A-1.1.1 The range of thermometers recommended are as given below :

a) – 38 to + 27°C

b) – 10 to + 55°C

c) 0 to 50°C

d) 0 to 65°C

e) 0 to 80°C

f) 35 to 120°C

g) 80 to 250°C (for bitumen tanks)

A-1.2 General Requirements

a) *Type* — Mercury in-glass, solid stem, gas (not air) filled except for thermometer recommended under **A-1.1.1**(a) where it will be an alcohol thermometer.

b) *Stem* — The stem shall be made of lead glass, or other suitable glass. It shall have an enamel back.

c) *Bulb* — The bulb shall be made of a suitable thermometric glass approved by the National Physical Laboratory or by ISI.

d) *Expansion and Contraction Chamber* — No enlargement of the bore shall be within 10 mm of any part of the scale.

e) *Graduation and Figuring* — The scale marks shall be clearly etched, and of uniform thickness, not exceeding 0·15 mm so that the marking is sufficiently sharp for easy reading. The marks shall be at right angle to the axis of the thermometer. When the thermometer is viewed from the front and is in a vertical position the marks shall all finish on a line, that is, the scale base, at the left-hand side parallel to the axis of the thermometer.

f) *Marking* — Each thermometer shall be marked with an identification number and the maker's or supplier's name or trade-mark. Each thermometer shall also be marked with the immersion at which it is to be used which shall be ' Total Immersion '.

NOTE — It is essential that the thermometers are marked with a material resistant to the action of petroleum products.

g) *Annealing* — Strain in the glass shall be reduced to a level sufficient to minimize the possibility of fracture due to mechanical or thermal shock.

h) *Stability* — Thermometers shall be artificially aged by means of a suitable heat treatment before graduation in order to secure stability.

j) *Verification* — For reference purposes thermometers shall be used which have been certified by National Physical Laboratory or any other competent authority duly approved by ISI (*see* **A-2.2**).

A-1.3 Special Requirements — Special requirements shall be in accordance with Table 1.

A-2. METHOD FOR PERIODICAL CHECKING OF LIQUID-IN-GLASS THERMOMETERS

A-2.1 The periodical check may be carried out without elaborate apparatus. A simple bath containing a suitable liquid to a depth of about 40 cm and fitted with a simple loop stirrer is suitable. A thermometer certified by the National Physical Laboratory or by some other national body authorized to issue such a certificate need not be used for the purpose of checking working thermometers, but the thermometer used as the standard shall be of the same type as the thermometer being checked. It shall be kept solely for this purpose and shall be checked yearly against a certified thermometer.

A-2.2 A set of certified thermometers duly approved by the National Physical Laboratory or any other competent authority duly approved by ISI should be available with the users for the purpose of checking the accuracy of the working thermometers in case of any dispute or for annual checking (*see also* **3.3.1.1**).

TABLE 1 SPECIAL REQUIREMENTS FOR LIQUID-IN-GLASS THERMOMETERS

[*Clause* A-1.1(a)]

SL No.	SPECIAL MARKING/ NAME	TANK THERMOMETER	BITUMEN TANKS	ANGLE-STEM
(1)	(2)	(3)	(4)	(5)
1.	Range, degrees Celsius	a) − 38 to + 27 b) − 10 to + 55 c) 0 to 50 d) 0 to 65 e) 0 to 80 f) 35 to 120	80 to 250	a) — 38 to + 27 b) — 10 to + 55 c) 0 to 50 d) 0 to 65 e) 0 to 80 f) 35 to 120
2.	Graduation, degrees Celsius	0·5	1	0·5
3.	Immersion, mm	Total	Total	As required
4.	Overall length, mm	310±5	310±5	As required
5.	Stem diameter, mm	6 to 7·5	6 to 7·5	6 to 7·5
6.	Bulb :			
	Shape	Cylindrical	Cylindrical	Cylindrical
	Length, mm	10 to 18	8 to 12	—
	Diameter	Not less than 5·5 mm. Not greater than stem	Not less than 5·5 mm. Not greater than stem	Not less than 5·5 mm. Not greater than stem
7.	Length of graduated portion, mm	210 to 240	210 to 230	210 to 230
8.	Distance from lowest limit to bottom of bulb, mm	50 to 60	50 to 60	Lowest graduation as required
9.	Longer lines at each, degree Celsius	1	5	Depending on range
10.	Figured at each, degree Celsius	5	10	do
11.	Expansion chamber to allow heating up to	50°C higher than the maximum temperature	300°C	40°C above upper limit of range
12.	Top finish	Plain	Plain	Plain
13.	Scale error not to exceed + or −, degree Celsius	a) 0·25 b) 0·25 c) 0·25 d) 0·25 e) 0·25 f) 0·5	1	a) 0·25 b) 0·25 c) 0·25 d) 0·25 e) 0·25 f) 0·5

NOTE — Where thermometers are required for use with top suspension armoured cases, they must be finished with a flattened button of suitable dimensions (*see* **3.3.2.2** and Fig. 4B).

A-2.3 In order to check a thermometer, it shall be attached to the standard thermometer with a rubber band so that the bulbs are at the same level. The thermometer with the standard thermometer attached shall then be inserted in the bath with the whole of the indicating columns immersed. The check may be carried out in a simple bath containing a suitable liquid to a depth of about 400 mm and fitted with a simple loop stirrer. When such a bath is used, the temperature of the bath shall be gradually raised to just above the required temperature, keeping the liquid in the bath well stirred. The source of heat shall then be removed and the stirring continued. When the temperature is steady and just on the point of falling, the readings on the thermometers shall be compared. The number of points checked on the scale shall be at least three, these should be preferably near the centres of the upper and lower halves of the scale, and the centre of the scale. Precaution shall be observed for allowing sufficient time to drain for thermometers filled with alcohol or toluene [*see* **3.3.1.1** (e)].

A-3. EMERGENT-STEM CORRECTION

A-3.1 The thermometers specified are graduated to read correctly when the bulb and the whole of the thermometric liquid column are immersed in the oil. If a small portion of the column is allowed to emerge from the oil to facilitate readings, the error will not be great, and can generally be neglected.

A-3.2 The correction for the emergent-stem is, however, of particular importance when reading the temperature of hot oils flowing through pipe-lines is determined with an ordinary liquid-in-glass thermometer in a thermo-well or where the stem of such an instrument is exposed to the direct rays of the sun.

A-3.3 A table of corrections should therefore be prepared for a thermometer installed under these conditions. The table should cover the range of operating conditions expected. The corrections for various lengths of emergent-stem and ambient temperature conditions may be estimated for practical purposes.

$$\text{Emergent-stem correction} = n\,\alpha\,(t - e)$$

where

t = observed temperature

n = number of degree graduations between the oil level (or the mouth of the thermo-well) and the observed reading;

e = average temperature of the emergent column;

α = apparent coefficient of cubical expansion in glass of the thermometric liquid, obtained by subtracting the coefficient of cubical expansion of glass from the coefficient of cubical expansion of the liquid. For mercury-in-glass, α is approximately 0·000 16.

NOTE — The average temperature (e) of the emergent-stem may be determined by attaching a small mercury-in-glass thermometer of suitable range to the stem of the main thermometer with a rubber band. The bulb of this ancillary thermometer should be placed in a position approximately corresponding to the centre of the emergent column, that is, at $n/2$.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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